JC03 Rec'd PCT/PTO 27 APR 2001

FORM PTO-1390 U S DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER

43877-115

U.S. APPLIC. NO. (if known, see 37 CFR 1.5)

09/830409

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/JP00/07659	October 30, 2000	October 28, 1999

TITLE OF INVENTION

LINEAR MOTOR COILS ASSEMBLY AND MANUFACTURING METHOD THEREOF

APPLICANT(S) FOR DO/EO/US

Yoichi SEKI and Taro HASEGAWA

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information.

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☐ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☐ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendment has NOT expired.
   d ☐ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U S.C 371(c)(4))
10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1 98.
12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☐ A FIRST preliminary amendment.
    ☐ A SECOND or SUBSEQUENT preliminary amendment.
14. ☐ A substitute specification.
15. ☐ A change of power of attorney and/or address letter
16. ☒ Other items or information.

    International Search Report prepared by JPO
    Forms PCT/IB/301 and PCT/IB/304

20277

PATENT TRADEMARK OFFICE

JJ08 Rec'd PCT/PTO 27 APR 2001

U.S. APPLIC. NO. (if known, see 37 CFR 1.50)	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER
09/830409	PCT/JP00/07669	43877-115

	CALCULATIONS	PTO USE ONLY
17. ☒ The following fees are submitted: **Basic National Fee (37 CFR 1.492(a)(1)-(5)):** Search Report has been prepared by the EPO or JPO — $860.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) — $690.00 No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1 445(a)(2)) — $710.00 Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO — $1,000.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) — $100.00		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$ 860.00	
Surcharge of $130 00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$	

Claims	Number Filed	Number Extra	Rate		
Total Claims	8 -20 =	0	x $18.00	$	
Independent Claims	2 -3 =	0	x $80.00	$	
Multiple dependent claim(s) (if applicable)			+ $270.00	$	
			TOTAL OF ABOVE CALCULATIONS =	$ 860.00	
Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity Statement must also be filed. (Note 37 CFR 1.9, 1.27, 1.28).				$	
			SUBTOTAL =	$ 860.00	
Processing fee of $130.00 for furnishing the English translation later than the ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$	
			TOTAL NATIONAL FEE =	$ 860.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +				$ 40.00	
			TOTAL FEES ENCLOSED =	$ 900.00	
				Amount to be: refunded	$
				charged	$

a. ☐ A check in the amount of $ _____ to cover the above fees is enclosed.

b. ☒ Please charge my Deposit Account No. 500417 in the amount of $ 900.00 to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 500417. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

McDERMOTT, WILL & EMERY
600 13th Street, N.W.
Washington, DC 20005-3096
(202) 756-8000
Facsimile (202) 756-8087

SIGNATURE
Paul Devinsky
NAME
28,553
REGISTRATION NUMBER
April 27, 2001
DATE

8/PRTS

09/830409

JC08 Rec'd PCT/PTO 27 APR 2001

Specification

Linear Motor Coils Assembly And Manufacturing Method Thereof

Field of the Invention

The present invention relates to a linear motor for generating linear movement. More particularly, the present invention relates to a linear motor coil assembly having a plurality of coils arranged in a line in the direction of linear motion.

Background Art

Machine tools are known that use a linear motor to cause a table to move linearly at high speed and to position the table with high precision. Recently, linear motors have become more widely used. Such motors do not a require conveying means such as a feed screw. A linear motor may be used in a machine tool when it is needed to generate a large thrust, and where more compact structures are needed. However, because of their compact size, linear motors generate more heat than rotary motors. The temperature rise associated with a linear motor may limit its rated thrust, and lower its mechanical positioning accuracy. In many cases, linear motors are encapsulated in a cover in order to prevent magnetic dust from infiltrating into the linear motor. Because of this encapsulation, insufficient natural cooling of the linear motor may result, making effective cooling of the linear motor an important consideration.

Japanese Laid-Open Patent Application 63-18956 discloses a cooling apparatus for a linear motor. The motor is equipped with a cooling tube at the bottom of a groove formed between adjoining pole teeth. This linear motor cooling tube will now be described in detail below with reference to Fig. 9, Fig. 10 and Fig.

11. A plurality of permanent magnets **3** having alternating magnetic poles are fixed in a line on the lower surface of a carrier **2** in the direction of movement. A fixed armature is made up of a plurality of T-shaped pole teeth **4**, a base **5** connecting the pole teeth, and a coil **7** wound around the teeth **4**. As clearly shown in Fig. 9, cooling tubes **8** are provided, one each at the bottom of grooves **6** formed by adjoining pole teeth **4**. The cooling tubes **8** comprise, for example, a tube **8A** which meanders around the grooves **6**, as shown in Fig. 10. A coolant, in gas or liquid form, circulates in the pipe **8A**. As shown in Fig. 11, the cooling tubes **8**, may comprise stair-shaped pipes **8B**. The pipes **8B** are equipped with headers **8a** and **8b** which extend parallel to a moving direction, opposite with respect to the base **5**, and a bridging section **8c**, bridging the headers **8a** and **8b**. The coolant is introduced from one end of the header **8a**, passes through the bridging section **8c** and is discharged from one end of the header **8b**.

Summary Of The Invention

An object of the present invention is to provide a linear motor coil assembly that efficiently dissipates heat generated in the coil.

Another object of the present invention is to provide a compact linear motor coil assembly.

Still another object of the present invention is to provide a simple method of manufacturing a linear motor coil assembly, having a high cooling efficiency.

These and other objects are achieved by providing, according to the present invention, a linear motor coil assembly for developing linear motion. The coil assembly comprises a plurality of coils arranged in a line in the direction of movement, respective coil shafts being arranged perpendicular to the direction of movement, and a flat cooling pipe, having a cross section that is elongated in a

direction parallel to the coil shafts and having folds into which the coils can be engaged, the cooling pipe meandering inside the plurality of coils.

The flat cooling pipe preferably has a plurality of clearance holes for passing coolant formed in a direction parallel to the coil shafts.

Alternatively, the flat cooling pipe for passing coolant may be formed by aligning and attaching a plurality of round pipes in a direction parallel to the coil shafts.

The flat cooling tube preferably has interleaved folds at least equal in number to the number of coils.

The linear motor coil assembly may also include cores, divided for each coil, around which the coils are wound.

According to the present invention, there is also provided a method of manufacturing a linear motor assembly for developing linear motion, comprising the steps of providing cores divided for each magnetic pole, winding coils around the respective cores, providing a flat cooling pipe having interleaved folds, at least equal in number to the number of coils, into which the coils may be engaged, fitting the core into the folds, and arranging the cores in a line on a base plate.

Other objects and novel features will become apparent upon consideration of the following description.

Brief Description Of The Drawings

Fig. 1 is a front elevation depicting an embodiment of a linear motor coil assembly of the present invention;

Fig. 2 is a plan view depicting the coil assembly of Fig. 1;

Fig. 3 is a cross sectional drawing showing a coil and a cooling tube in Fig. 1 in magnified form;

Fig. 4 is a cross sectional drawing showing conveyance of the heat generated in the coils to the cooling tube;

Fig. 5 is a perspective view depicting another embodiment of the cooling tube in Fig. 1;

Fig. 6A, Fig. 6B, Fig. 6C and Fig. 6D are plan drawings depicting a method of manufacturing a linear motor coil assembly;

Fig. 7 is a perspective view of a coil assembly viewed in the direction of arrow B in Fig. 6;

Fig. 8 is a perspective view showing the coil assembly of Fig. 1 covered by an insulating resin;

Fig. 9 is a plan view of a linear motor according to the background art;

Fig. 10 is a cross sectional view of one example of a cooling tube taken along line A - A in Fig. 9; and

Fig. 11 is a cross sectional view of another example of a cooling tube taken along line A - A in Fig. 9.

Preferred Embodiment of The Invention

A linear motor coil assembly according to an embodiment of the present invention will now be described with reference to Fig. 1, Fig. 2, Fig. 3 and Fig. 4.

A linear motor coil assembly **12** for developing motion in the direction of a horizontal linear axis X has a base plate **11**, cores **13** having coils **14** mounted thereon. The coil assembly **12** may constitute either a mover or a stator. Reference numeral **G1** in Fig. 1 represents a gap formed between a stator and a mover. The base plate **11** has a horizontal upper surface. The cores **13** divided for each magnetic pole and aligned in a line in the direction of the linear axis X are attached to the upper surface of the base plate **11** using screws **19**. A plurality of holes **18** for the

screws **19** are formed in the base plate. The cores **13** are preferably formed by laminating silicon-steel plates and welding or gluing them together. As illustrated in Fig. 2, the cores **13** extend parallel to each other in a horizontal direction Y perpendicular to the linear axis X. As illustrated in Fig. 3, a gap **G2** is formed between pole faces **13a** of adjoining cores **13**. In order to make the gap **G2** as small as possible, the pole faces **13a** of the cores **13** protrude in the direction of the linear axis X. The size of the gap **G2** is preferably maintained at a value about double the gap **G1**. A small gap **G2** reduces undesirable torque ripple. A yoke section **13b** is formed connecting adjoining cores **13**, and holes **13c** for screws **19** are formed in the yoke section **13b**. In the illustrated embodiment, a set of insulators **15**, for insulating the coils **14**, are inserted into the cores **13**. The coils **14** are wound around respective cores **13** via insulators **15**, preferably without overlapping. The coil axes Z are parallel to each other, and perpendicular to the linear axis X. The insulators **15** may, for example, be made of compact liquid crystal polymer resin capable of being thinly formed and having high thermal conductivity. As illustrated in Fig. 2, the insulators **15** have a generally U-shaped horizontal cross section, and a set of insulators are fit onto each core **13**. Tapered insulators **16** for preventing damage to the finish, e.g., enamel paint, of the coils **14** are preferably wrapped around the outside of the coils **14**. A flat cooling tube **20**, arranged so as to meander around the inside of the coils **14**, is arranged in the direction of the linear axis X. The cooling tube **20** is preferably made of extruded aluminum. The cooling tube **20** is preferably glued to the coils **14**, and the insulators **16** improve adherence between the coils **14** and the cooling tube **20**. As illustrated in Fig. 3, the cooling tube **20** has a cross section elongated parallel to the coil axes Z, and is arranged higher than the height H1 of the yoke section **13b**. The length of the elongated cross section is preferably

the same as, or slightly larger than, the length L of the coils **14** in the axial direction. As a result, the cooling tube **20** is glued to almost the entire outer surface of the coils **14**, which are a source of heat. A plurality of holes **25**, through which coolant flows, are formed in the cooling tube **20** in a direction parallel to the coil axes. Preferably, the cooling tube **20** does not have any branches, which means that no stagnation occurs in the flow of coolant. As shown by the arrows in Fig. 4, heat generated in the coils **14** which is conducted to an outer side is directly cooled by coolant inside the cooling tube **20**. Heat conducted from the coils **14** to the cores **13** is transferred through pole surfaces **13a** close to the cooling tube **20** and the yoke section **13b** to the cooling tube **20**.

Fig. 5 illustrates another example of the cooling tube **20**. The cooling tube **20** of Fig. 5 has a plurality of round copper pipes arranged parallel to the coil axes Z. Adjoining copper pipes **26** are preferably joined by brazing. The two ends **20a** and **20b** of the cooling tube **20** are connected to respective manifolds **21** and **22**, preferably by welding.

A method of manufacturing a coil assembly according to the present invention will now be described in detail below with reference to Fig. 6A, Fig. 6B, Fig. 6C, Fig. 6D.

As shown in the exemplary embodiment of Fig. 6A, cores at two locations, corresponding to the head and tail of a row of cores are temporarily attached to an upper surface of a base plate **11** using screws **19**. In the illustrated embodiment, a row of cores is made up of nine cores **13**. The coils **14** are wound around the cores **13** using a coil winding machine. Since the cores are divided for each coil **14**, winding of the coils **14** is simple. As shown in Fig. 6B, a flat cooling tube **20** having interleaved folds at least equal in number to the number of coils **14**,

is provided in the illustrated embodiment a flat cooling tube **20** having nine interleaved folds is provided. The folds of the cooling tube **20** are formed to correspond to the outline of the coils **14**, so that the coils **14** fit into the folds. The two ends of the cooling tube **20** are fixed preferably by welding, to elongated holes formed in manifolds **21** and **22**. The cooling tube **20** is moved horizontally, and the folds of the cooling tube **20** fit into two coils **14** on the base plate **11**. In the illustrated embodiment, three cores **13** are then moved horizontally, and inserted into folds of the cooling tube **20**. Then, as shown in Fig. 6C, an odd number, in this case five, cores of the row of cores are arranged on the upper plane of the base plate. Since the cores are inserted in the direction in which the coils are wound, damage to the coils is unlikely. An even number of cores of the core row, in this case four, are then moved horizontally and inserted into folds of the cooling tube **20**. One of the manifolds **21** is fixed to one end of the base plate **11**. All of the cores **13** are then fixed to the base plate **11** using screws **19**. As shown in Fig. 6D and Fig. 7, a cylindrical member **23** is vertically attached to the other end of the base plate **11**. The cooling tube **20** remaining at the other end of the base plate **11** is bent around the center of the cylindrical member **23**. Then, the other manifold **22** is fixed to one end of the base plate **11**.

After lead wires of the coils **14** have been located on the outer side of the base plate, the coil assembly **12** may be covered with a box-shaped frame. The frame is filled with insulating resin until the pole faces **13a** of the cores **13** are covered. The fixed resin compact may then be finished to the specified dimensions so as to expose the pole faces **13a**.

Fig. 8 depicts the coil assembly covered with the insulating resin as described above. Where the insulating resin sufficiently permeates into the coil

assembly **12**, there is no need for the insulators **16**.

The illustrated embodiment has been selected simply to describe the essence and practical application of the present invention, the scope of which is defined solely by the appended claims.

What is claimed is:

1. A linear motor coil assembly for developing linear motion, comprising:

a plurality of coils arranged in a line in a direction of movement, each coil having an associated coil shaft, said coil shafts being perpendicular to the direction of motion; and

a flat cooling tube, said cooling tube having a cross section elongated in a direction parallel to the coil shafts and folds into which said coils are adapted to engage, said cooling tube meandering inside the plurality of coils.

2. The linear motor coil assembly according to claim 1, wherein the flat cooling tube has a plurality of clearance holes for passing coolant, said clearance holes being formed in a direction parallel to the coil shafts.

3. The linear motor coil assembly according to claim 1, wherein the flat cooling tube comprises a plurality of round pipes for passing coolant, said pipes being aligned and attached in a direction parallel to the coil shafts.

4. The linear motor coil assembly according to claim 1, wherein the flat cooling tube has interleaved folds at least equal in number to the number of coils.

5. The linear motor coil assembly according to claim 1, wherein the elongated cross section of the flat cooling tube is the same as, or slightly larger than, the length of the coils in an axial direction.

6. The linear motor coil assembly according to claim 1, further comprising cores, divided for each coil, around which the coils are wound.

7. The linear motor coil assembly according to claim 6, further comprising a base plate, the cores being fixed to the base plate in a line generally parallel to the direction of motion.

8. A method of manufacturing a linear motor assembly for developing linear motion, comprising the steps of:

providing a plurality of cores divided for each magnetic pole;

winding coils around the respective cores;

providing a flat cooling tube having interleaved folds, the number of folds being at least equal to the number of coils, said folds being changeable by the coils;

fitting the core into the folds; and

arranging the cores in a line.

ABSTRACT

A linear motor coil assembly (12) comprises a plurality of coils (14) arranged in a line in a direction of movement and having respective coil shafts perpendicular to the direction of movement of the motor is provided. A flat cooling tube (20) is arranged to meander inside the plurality of coils. The cooling tube has a cross section elongated in a direction parallel to the coil axes, and a plurality of clearance holes (25) through which coolant flows are formed inside the cooling tube. The cooling tube has interleaved folds at least equal in number to the number of coils. The coils being fitted into these folds. At the time of manufacture of the coil assembly, the coils are wound around cores that are divided for each coil, and the cores are inserted into the folds of the cooling tube. A method of manufacturing a linear motor assembly having the aforesaid cooling tube is also disclosed.

FIG.1

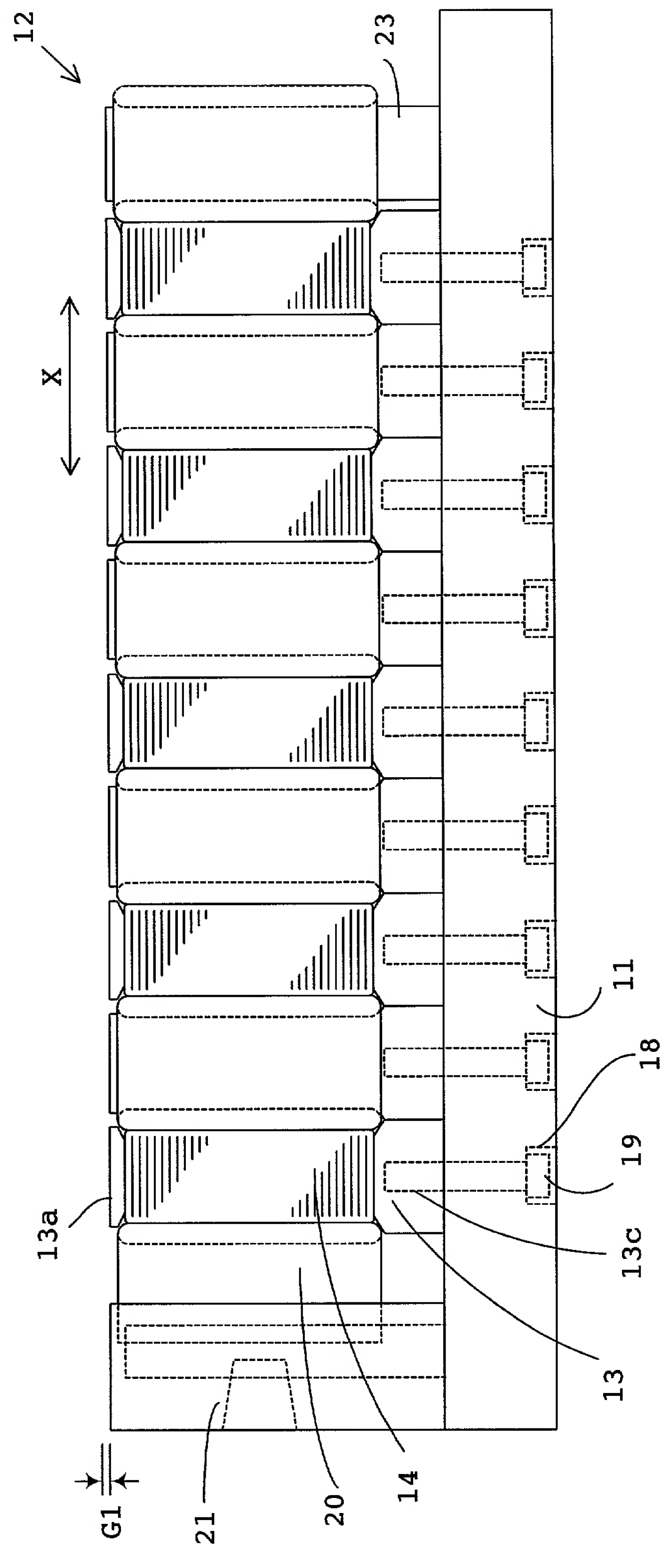

FIG.2

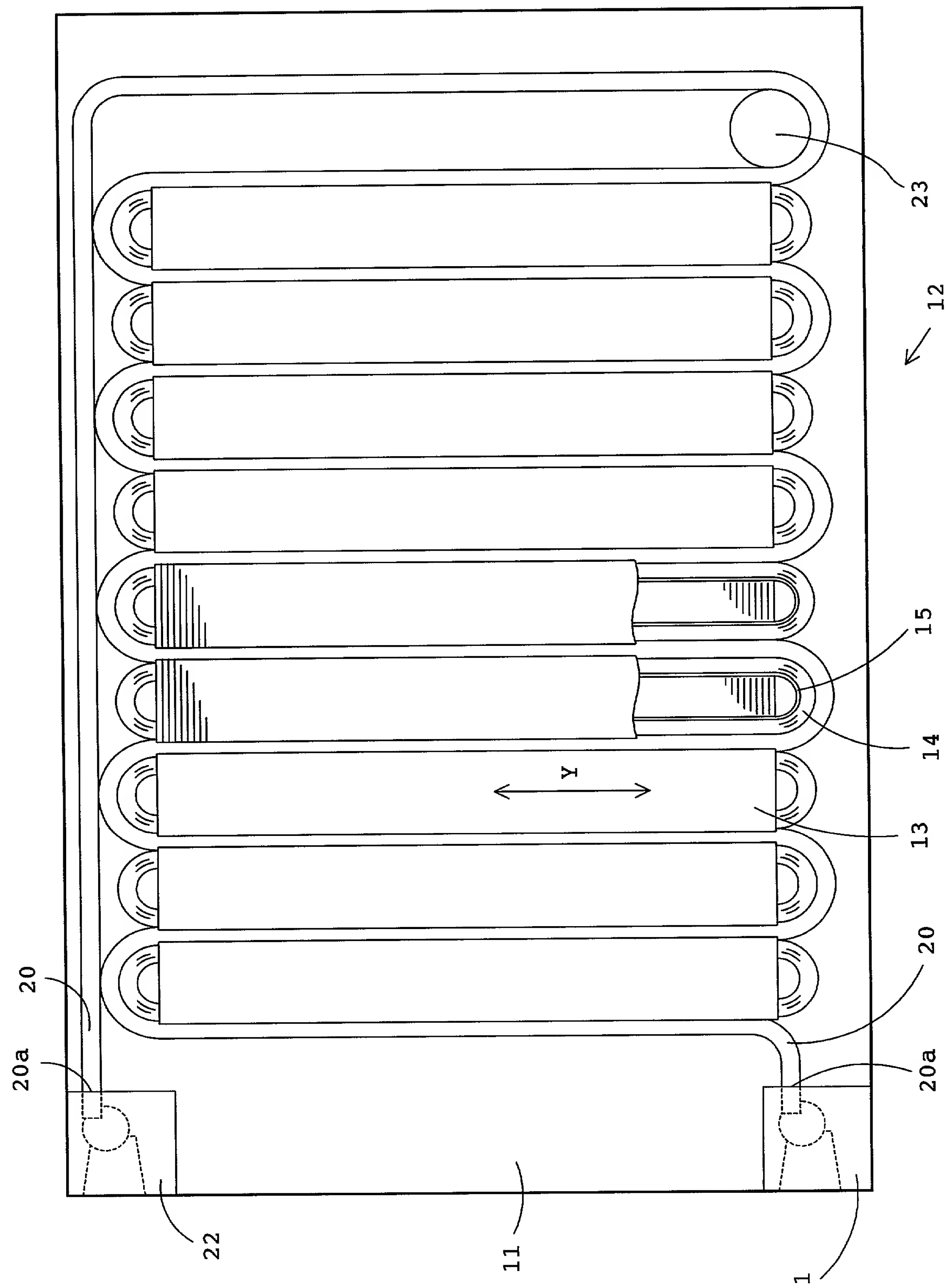

FIG.3

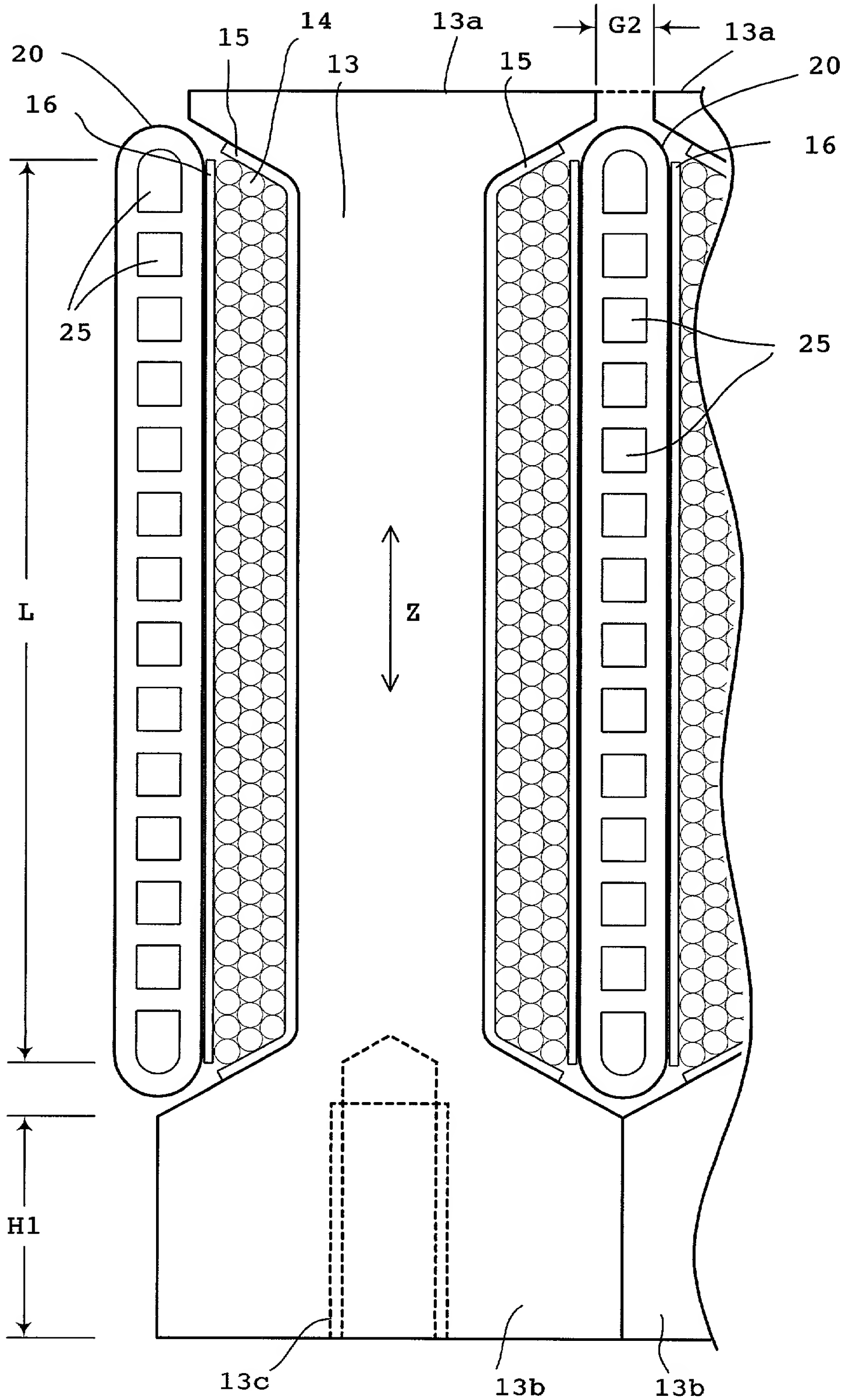

FIG.4

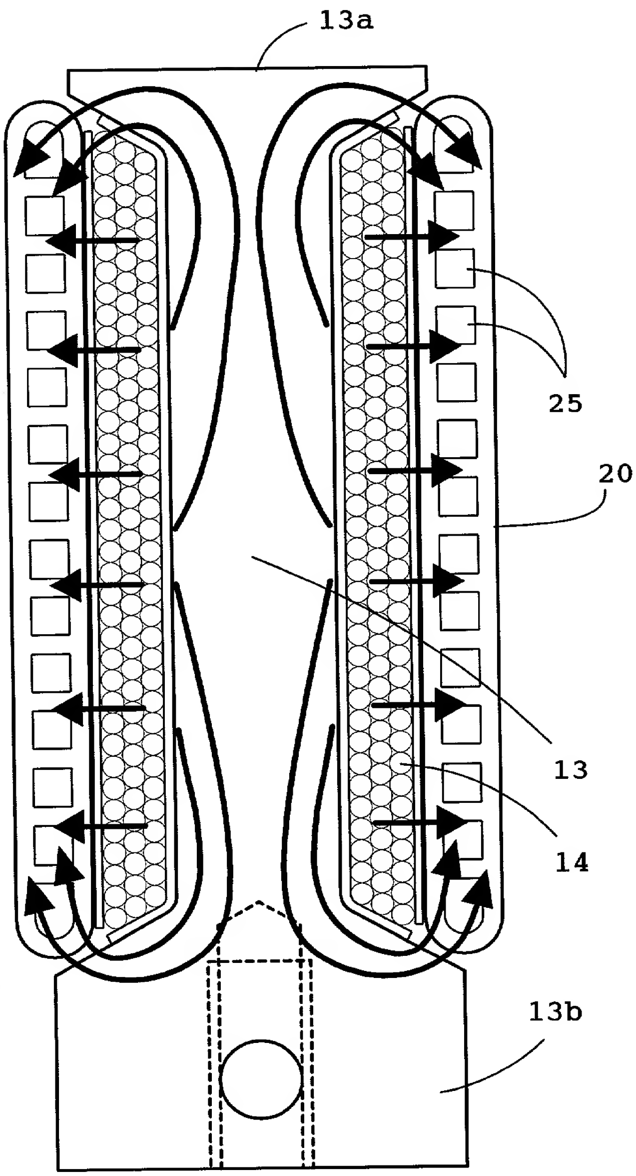

FIG.5

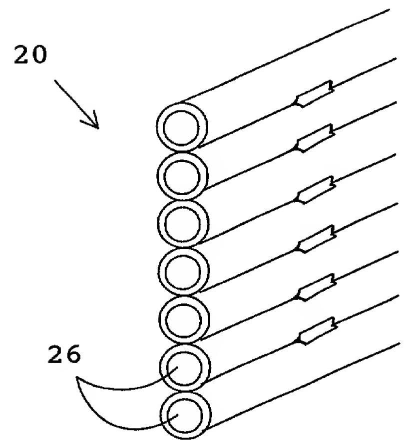

FIG.8

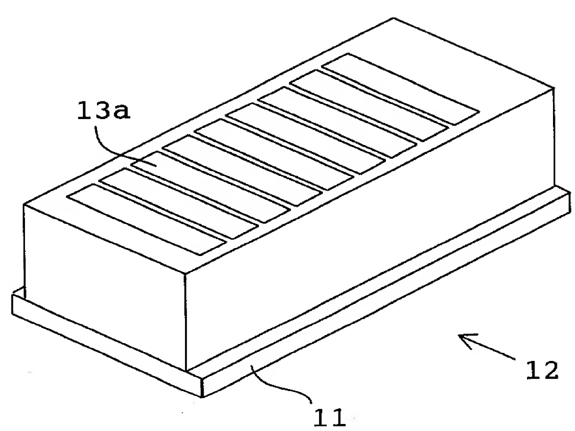

FIG.6A

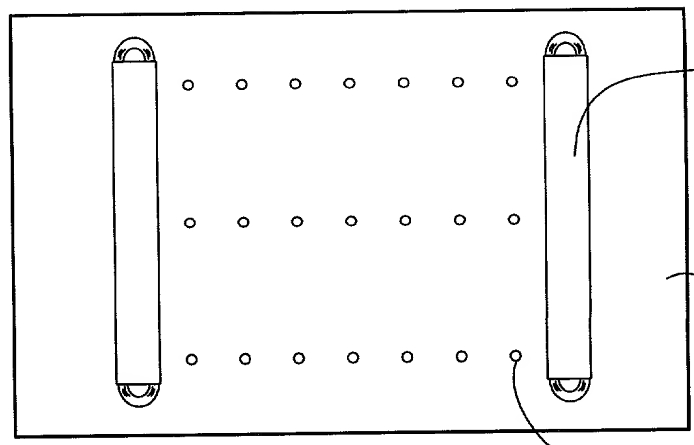

FIG.6B

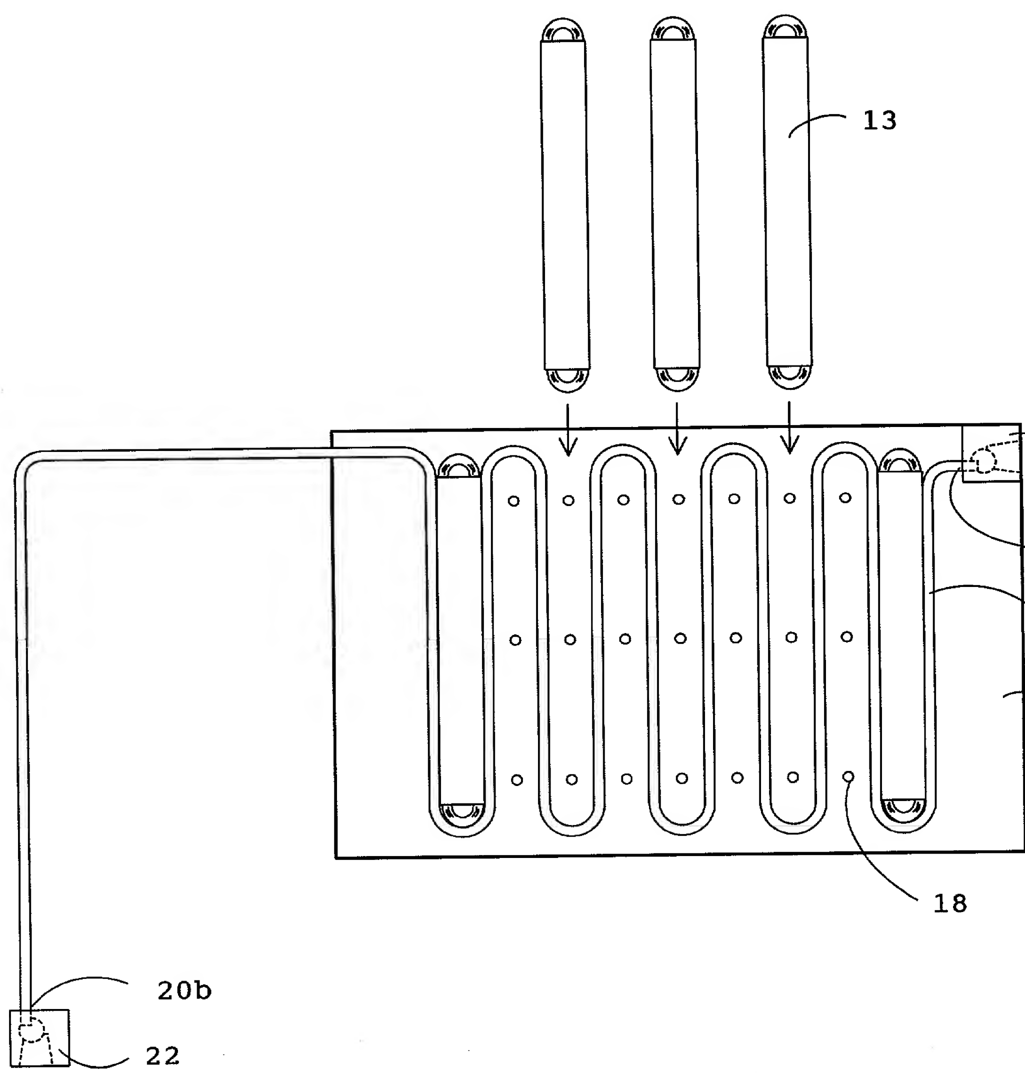

FIG.6C

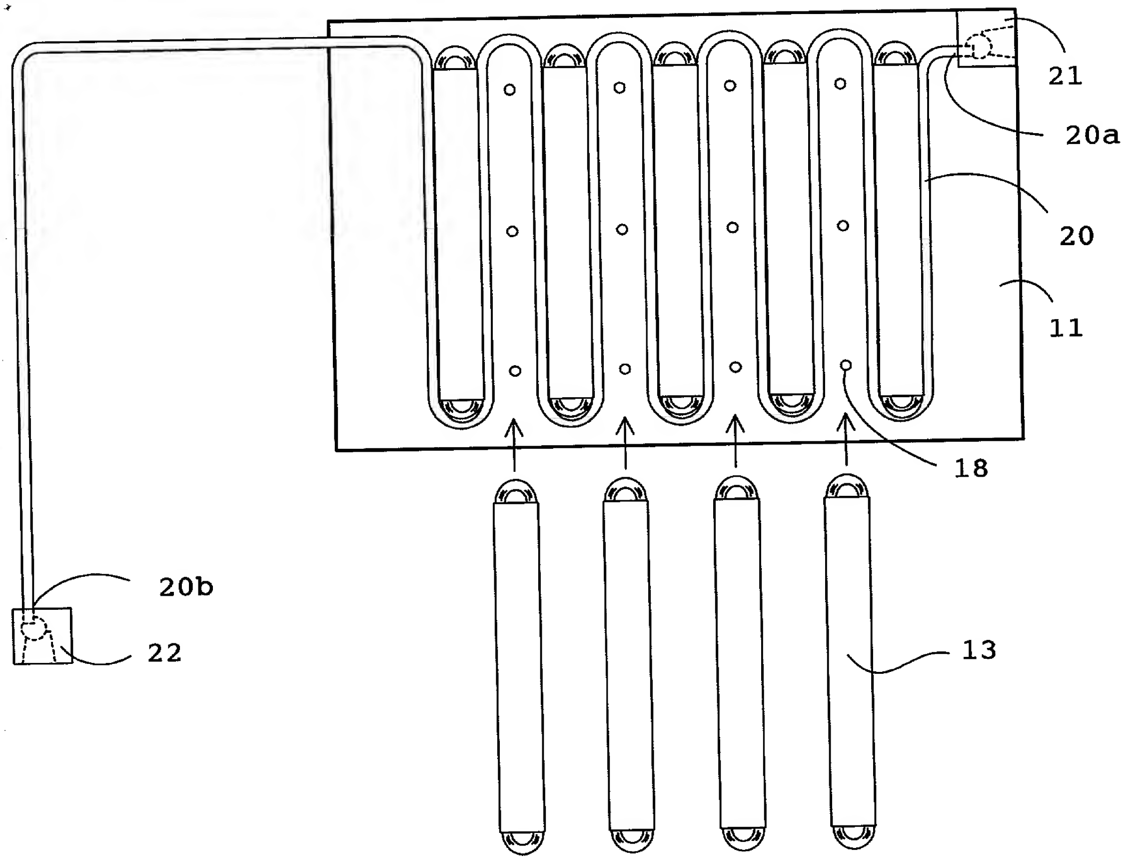

FIG.6D

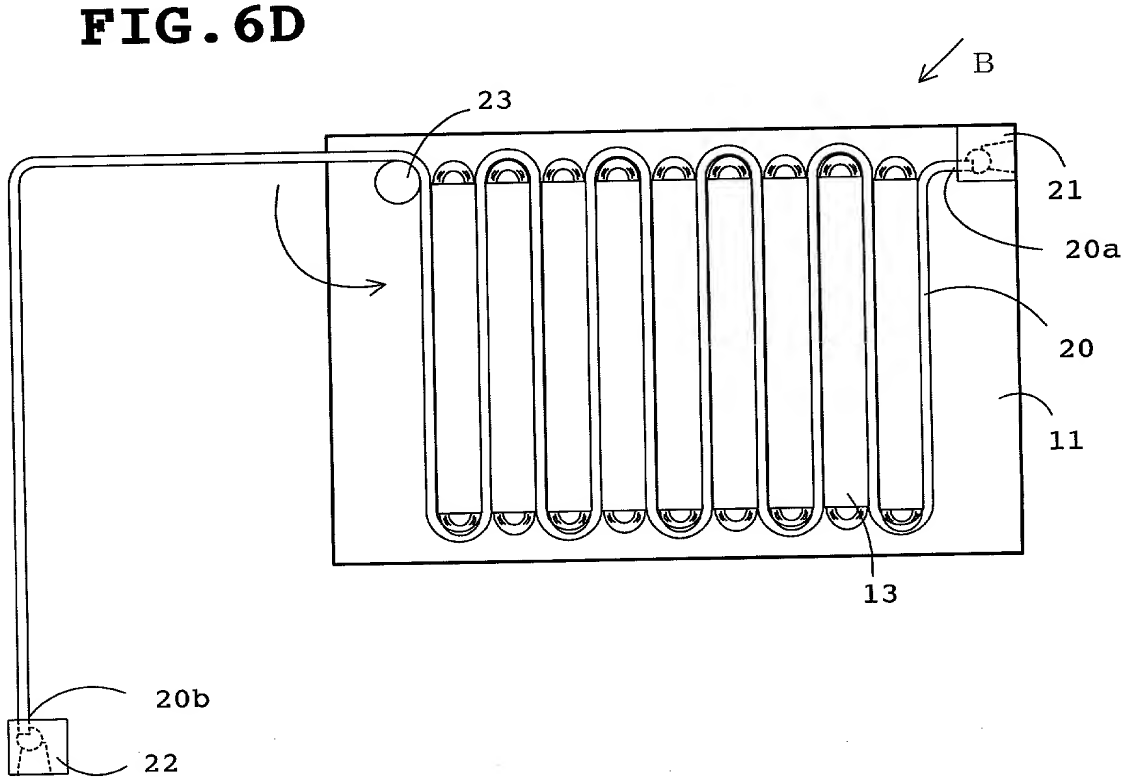

FIG. 7

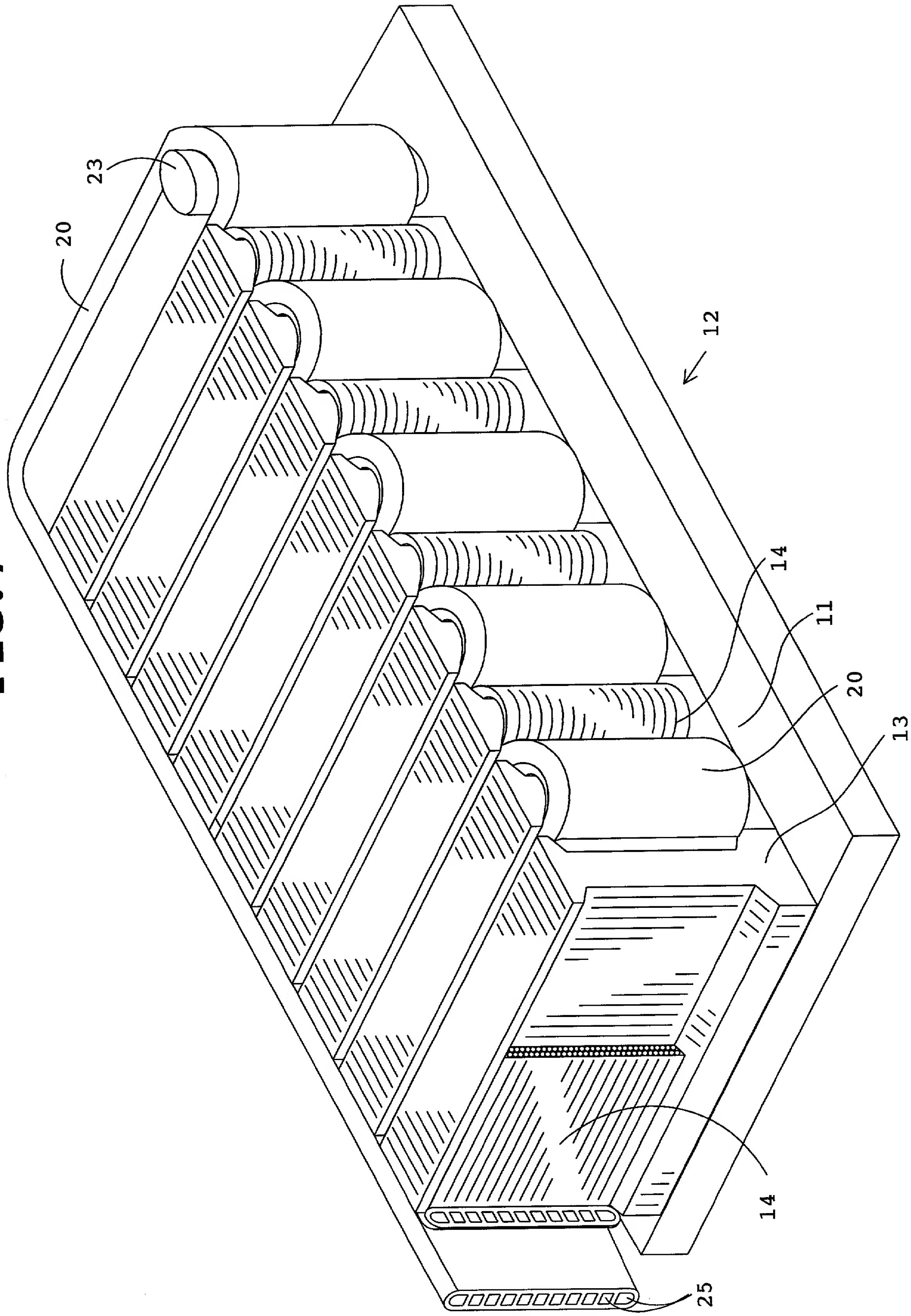

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FIG.9

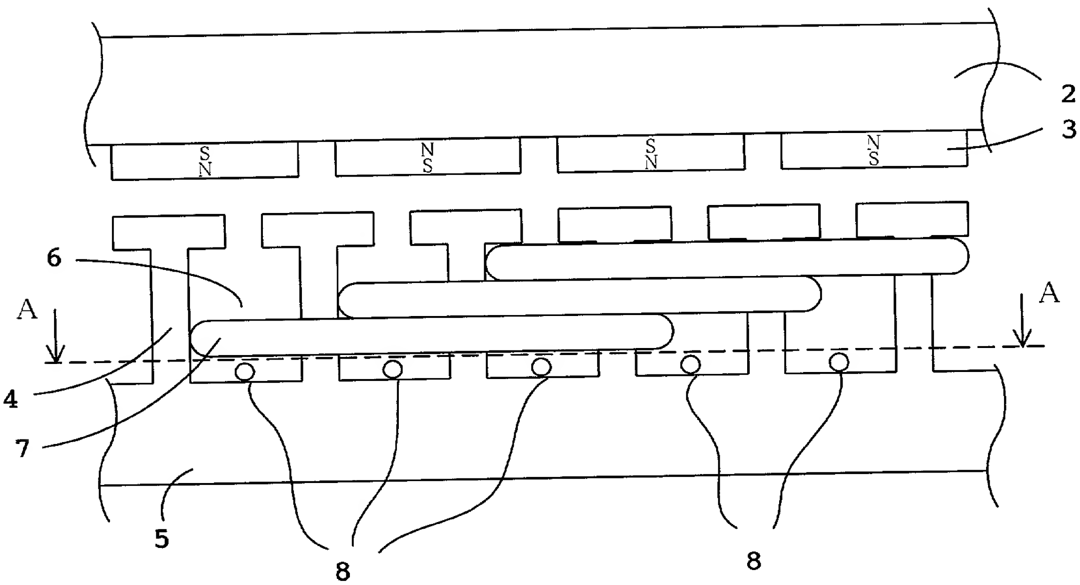


FIG.10

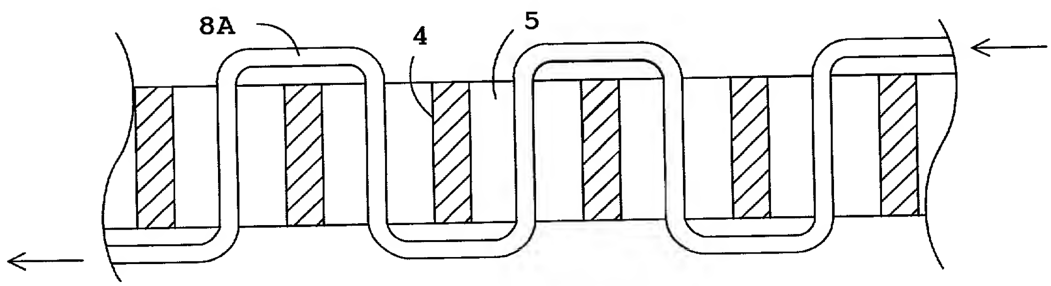
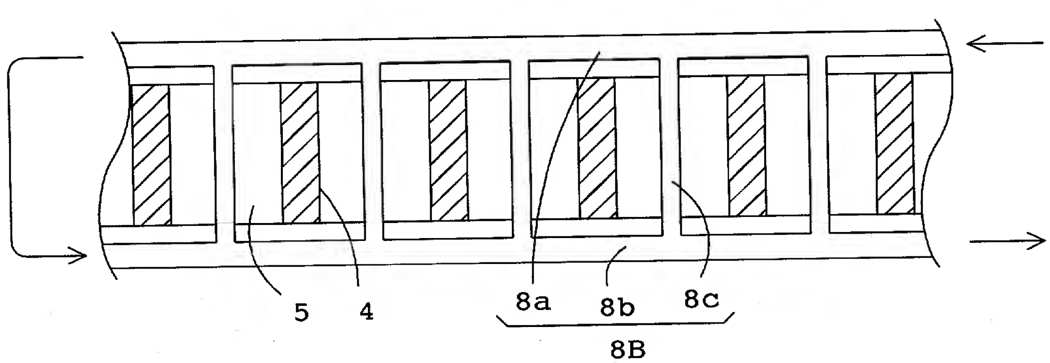


FIG.11



COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY (Includes Reference to PCT International Application(s)	Attorney's Docket Number 043877-0115

As below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

LINEAR MOTOR COILS ASSEMBLY AND MANUFACTURING METHOD THEREOF

the specification of which:

☒ is attached hereto.

☐ was filed as United States application Serial No. ______

on ______

and was amended on ______ (if applicable).

☒ was filed as PCT international application Number PCT/JP00/07669

on October 30, 2000

and was amended under PCT Article 19 on ______ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is known to me to be material to patentability in accordance with Title 37, Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, §119(a)-(d) or Section 365(b) of any foreign and/or international application(s) for patent or inventor's certificate or Section 365(a) of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed:

PRIOR FOREIGN/PCT APPLICATION(S) AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. 119:

COUNTRY (If PCT, indicate "PCT")	APPLICATION NUMBER	DATE OF FILING (day, month, year)	PRIORITY CLAIMED UNDER 35 USC 119
Japan	JP 11-307199	October 28, 1999	☒Yes ☐ No
PCT	PCT/JP00/07669	October 30, 2000	Yes

I hereby claim the benefit under 35 USC §119(e) of any United States provisional application(s) listed below.

PRIOR PROVISIONAL APPLICATION(S):

Application Number	Filing Date

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s), or §365(c) of any PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in that~~/those pri~~or application(s) in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, §1.56 which occurred between the filing date of the prior application(s) and the national or PCT international filing date of this application.

PRIOR U.S. APPLICATIONS OR PCT INTERNATIONAL APPLICATIONS DESIGNATING THE U.S. FOR BENEFIT UNDER 35 U.S.C. 120:

U.S. APPLICATIONS		STATUS (Check One)		
U.S. Application Number	U.S. Filing Date	Patented	Pending	Abandoned

PCT APPLICATIONS DESIGNATING THE U.S.					
PCT Application No.	PCT Filing Date	U.S. Serial Numbers Assigned *(if any)*			
PCT/JP00/07669	October 30, 2000				

POWER OF ATTORNEY: As named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith: Stephen A. Becker, Reg. No. 26,527; John G. Bisbikis, Reg. No. 37,095; Christopher D. Bright, Reg. No. 46,578; Daniel Bucca, Reg. No. 42,368; Kenneth L. Cage, Reg. No. 26,151; Jennifer Chen, Reg. No. 42,404; Bernard P. Codd, Reg. No. 46,429; Thomas A. Corrado, Reg. No. 42,439; Lawrence T. Cullen, Reg. No. 44,489; Paul Devinsky, Reg. No. 28,553; Margaret M. Duncan, Reg. No. 30,879; Shamita De. Etienne-Cummings, Reg. No. 46,072; Ramyar M. Farid, Reg. No. 46,692; Brian E. Ferguson, Reg. No. 36,801; Michael E. Fogarty, Reg. No. 36,139; John R. Fuisz, Reg. No. 37,327; Willem F. Gadiano, Reg. No. 37,136; Keith E. George, Reg. No. 34,111; Matthew V. Grumbling, Reg. No. 44,427; John A. Hankins, Reg. No. 32,029; Joseph Hyosuk Kim, Reg. No. 41,425; Eric J. Kraus, Reg. No. 36,190; Catherine Krupka, Reg. No. 46,227; Jack Q. Lever, Reg. No. 28,149; Raphael V. Lupo, Reg. No. 28,363; Michael A. Messina, Reg. No. 33,424; Dawn L. Palmer, Reg. No. 41,238; Joseph H. Paquin, Jr., Reg. No. 31,647; Scott D. Paul, Reg. No. 42,984; William D. Pegg, Reg. No. 42,988; Robert L. Price, Reg. No. 22,685; Gene Z. Rubinson, Reg. No. 33,351; Joy Ann G. Serauskas, Reg. No. 27,952; Daniel H. Sherr, Reg. No. 46,425; David A. Spenard, Reg. No. 37,449; Arthur J. Steiner, Reg. No. 26,106; David L. Stewart, Reg. No. 37,578; Wesley Strickland, Reg. No. 44,363; Michael D. Switzer, Reg. No. 39,552; Leonid D. Thenor, Reg. No. 39,397; Daniel S. Trainor, Reg. No. 43,959; Cameron K. Weiffenbach, Reg. No. 44,488; Aaron Weisstuch, Reg. No. 41,557; Edward J. Wise, Reg. No. 34,523; Alexander V. Yampolsky, Reg. No. 36,324; and Robert W. Zelnick, Reg. No. 36,976 , all of McDermott, Will & Emery.

Send Correspondence to:	Direct Telephone Calls to: *(name and telephone number)* 46
Paul Devinsky McDERMOTT, WILL & EMERY 600 13th Street, N.W. Washington, D.C. 20005-3096	(202) 756-8369

201	Full Name of Inventor	Family Name SEKI	First Given Name Yoichi	Second Given Name
	Residence and Citizenship	City Fukui	State or Foreign Country Japan JPX	Country of Citizenship Japan
	Post Office Address	Post Office Address	City	State & Zip Code/Country
202	Full Name of Inventor	Family Name HASEGAWA	First Given Name Taro	Second Given Name
	Residence and Citizenship	City Fukui	State or Foreign Country Japan JPX	Country of Citizenship Japan
	Post Office Address	Post Office Address	City	State & Zip Code/Country
203	Full Name of Inventor	Family Name	First Given Name	Second Given Name
	Residence and Citizenship	City	State or Foreign Country	Country of Citizenship
	Post Office Address	Post Office Address	City	State & Zip Code/Country

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Signature of Inventor 201:	Signature of Inventor 202:	Signature of Inventor 203:
[signature]	Taro Hasegawa	
Date March 22, 2001	Date March 22, 2001	Date